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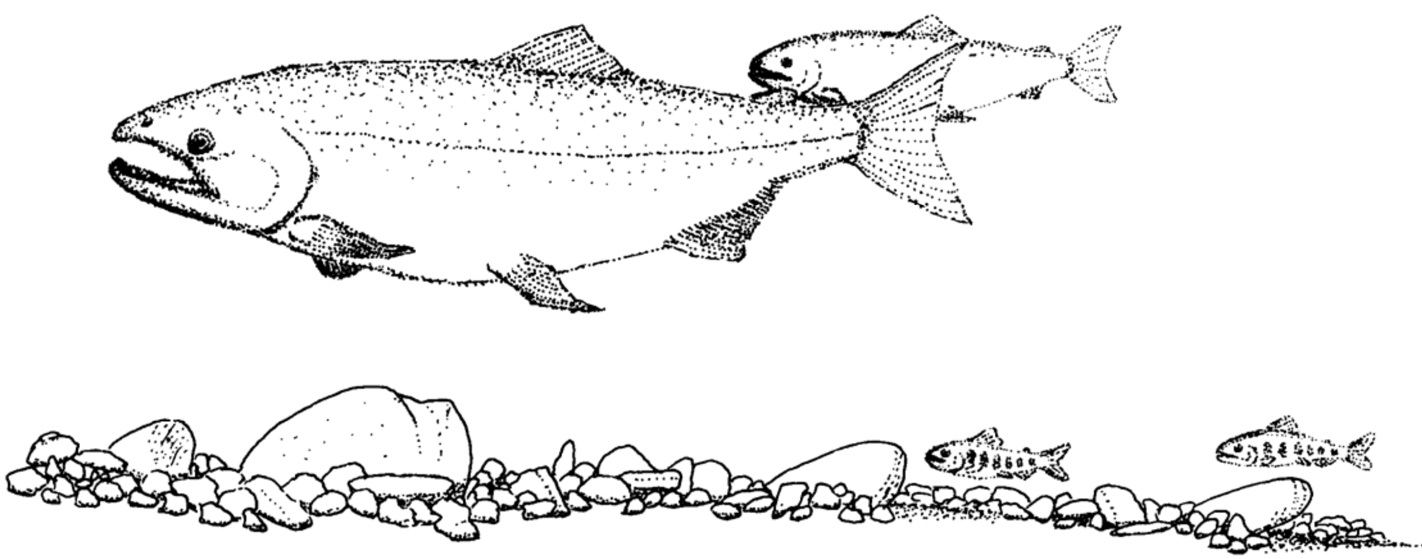
Adult Pink Salmon Migratory Barriers and Habitat Utilization in the Dungeness River



ADULT PINK SALMON MIGRATORY BARRIERS

AND HABITAT UTILIZATION IN THE DUNGENESS RIVER

by

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Abstract

We evaluated potential migratory barriers and habitat use by adult summer pink salmon (*Oncorhynchus gorbuscha*) in the Dungeness River, Washington. Evaluation of migratory barriers involved monitoring four sites containing long, steep, shallow riffles, and collecting water temperature throughout the migration period. Habitat use was assessed by identifying holding locations of adult summer-run pink salmon using snorkeling techniques and measuring physical habitat characteristics at those locations. Habitat measurements included water depth, focal depth, water and focal current velocity, substrate, cover, and shade. Volunteers did not observe any adult pink salmon migrating through or holding at three potential physical barriers (long, steep riffles). These results may have been influenced by greater than normal late summer discharge which was due to greater than normal snow pack during the previous winter. Water temperatures were also cooler than those thought to result in significant migration delays. However, we observed pink salmon migrating during the daytime during our snorkel surveys. Adult pink salmon did not show a strong selection of different river habitat types. They preferred shaded or partially shaded areas to areas lacking shade. Adult pink salmons used cobble and gravel more than boulder and silt; however, use appeared to be similar to substrate availability. Numbers of holding adult pink salmon were positively influenced by the surface area of cover classified as in-stream objects, which provided shelter from current velocities. However, this relationship explained little of the overall variation in numbers of holding pink salmon. Adult pink salmon used areas with cover more than areas lacking cover. Adult pink salmon generally held in water greater than 1 m deep, were generally close to the bottom, and within 1.5 m of cover. Mean column and focal velocities averaged 57.8 cm/s and 30.1 cm/s, respectively.

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Introduction

Dungeness River pink salmon (*Oncorhynchus gorbuscha*) populations have been depressed since the early 1970s, with the fall run designated in critical status (WDF et al. 1993). Population trends of pink salmon in the Dungeness River were consistent with overall Puget Sound pink salmon trends until 1981. Dungeness pink salmon production continued to decrease after 1981, while total Puget Sound pink salmon production began to increase. This suggests that problems within the Dungeness River system resulted in the decline of the Dungeness pink salmon population (Lichatowich 1992; Hard et al. 1996). Within the nearby Elwha River, pink salmon are considered critically depleted (WDF et al. 1993), and restoration efforts for upper Elwha River pink salmon runs have focused on future transfers of Dungeness summer-run pink salmon (DOI 1994).

Dungeness pink salmon are divided into distinct summer and fall runs. The summer-run pink salmon population is a wild, native, odd-year stock that enters the Dungeness River in late July and generally ends spawning in mid-September. The summer-run pink salmon spawn in the mainstem from river kilometer (RKM) 15.5 up to the limits of anadromous passage in the Gray Wolf River and the Dungeness mainstem, as well as in the lower 2.4 km of Gold Creek (Hiss 1995). Summer-run pink salmon hold in lower mainstem to mature prior to migrating to upstream spawning habitat. The fall-run pink salmon are a wild, native, odd-year stock that apparently enters the Dungeness River in mid-September and ends spawning by late October. The fall-run spawns in the lower 9.6 km of the Dungeness River.

Low instream flows have been identified as one of the factors influencing pink salmon escapement within the Dungeness River, and are believed to impair adult migrations to spawning grounds (Orsborn and Ralph 1994; Hiss 1995; Hard et al. 1996). Low instream flows may directly and indirectly influence adult salmonids. Low instream flows can increase spawner densities within quality spawning habitat, which can lead to increased predation on adults that are in shallow water or are overcrowded. Low instream flows can create migratory blocks through physical barriers, such as long steep riffle stretches with shallow depths, or through temperature barriers where decreased water depths have increased temperature. Overcrowding and migration barriers can result in death or stress to adults which in turn affects overall egg production (Wickett 1958; Helle 1966; Haring 1999). Of particular concern within the Dungeness River system is the potential for migration barriers due to low instream flows, through both physical and temperature barriers. The influence of irrigation withdrawals has the most direct effect on instream flows in the Dungeness River, which are exacerbated by the physical characteristics of this river system. In addition, the largest irrigation withdrawals coincide with the timing of summer-run pink salmon spawning migrations.

In this study, monitoring was implemented at locations of potential migratory blocks, and additional water temperature data were collected to determine whether significant passage barriers were present during the summer-run pink salmon migration in the Dungeness River. We also surveyed designated reaches to determine holding habitat utilization by adult summer-run pink salmon. The examination of potential passage barriers, and holding habitat for summer-run pink salmon will further restoration efforts towards increasing escapement within the Dungeness River, which may in turn increase the potential for broodstock transfer to the upper Elwha River.

Study Area

The Dungeness River originates from the Olympic Mountains and travels 51.3 km before flowing into Dungeness Bay, and entering the Strait of Juan de Fuca (Figure 1). As the largest tributary, the Gray Wolf River is 30 km long, and joins the mainstem of the Dungeness River at RKM 25.4. The Dungeness River basin was largely formed when the last major ice sheet began to recede 14,000 years ago during the cordilleran glaciations. Much of the sediment carried from the mountains to the lowlands and to marine waters is reworked glacial drift that was carried into the mountain terrain from these advancing and regressing glaciations (Jamestown S'Klallam Tribe 1994). The Dungeness River has a relatively steep gradient from the headwaters to RKM 25.4, where it becomes more moderate, and the lower 17.7 km of mainstem range from 0.5 to 2 percent gradient.

Historically, the lower 16.1 km of the Dungeness River was a naturally unconfined, alluvial fan that was characterized by meandering and braided channels. However, since dikes and levees have been added, much of the lower mainstem is now confined with aggraded, unstable bedloads. High rates of sediment transport and accumulation have caused sediment loads that are deposited in the river at a rate that exceeds the river's ability to transport them (Jamestown S'Klallam Tribe 1994). As velocity slows in lower reaches, larger rock is deposited first, while smaller silt and clay are carried downstream and out into tidal areas. An aggraded streambed absorbs more water, which would normally be contributing to river surface flows. Normally, as flow increases along with an increased drainage area, channel size widens in a downstream direction. However, the Dungeness River does not have a constant increase in channel width downstream, due to the constricting influence of five bridges. The bridges force the flows to slow down, causing the sediment load to drop, which in turn raise the upstream bed and water surface elevations enough for flows to accelerate through the bridge. When flows decrease, new channels are created around the deposited material (Orsborn and Ralph 1994). The lower river is also prone to elevated water temperatures, because of the wide open valley form which is dominated by larger substrates that have an increased rate of thermal transfer to the surrounding waters (Orsborn and Ralph 1994). During low river flows, these elevated temperatures are intensified during periods of high irrigation withdrawal.

Human activities have had a large influence on river flows within the Dungeness River. Approximately 170 miles of irrigation canals and ditches spread throughout the river delta. There are five irrigation diversions between RKM 10.9 and 17.7, which withdraw the greatest amount of water in the months of July, August and September. These months coincide with the migration of summer-run pink salmon and are traditionally the lowest flow months in the Dungeness River (Orsborn and Ralph 1994; Haring 1999). In recognition of this conflict, and as a part of the Dungeness-Quilcene Plan developed in 1994, water users in the Dungeness basin agreed to voluntarily withdraw no more than 50 percent of the river flows on an instantaneous basis (Seiter et al. 2000). Additional human impacts include increased road construction between 1965 and 1983 in the upper watershed in conjunction with increased timber harvest, as well as dike and levee building for flood control in the lower river. Major landslides within the Gold and Silver Creek subbasins have also contributed negatively to streamflows and sediment bedloads within the Dungeness River.

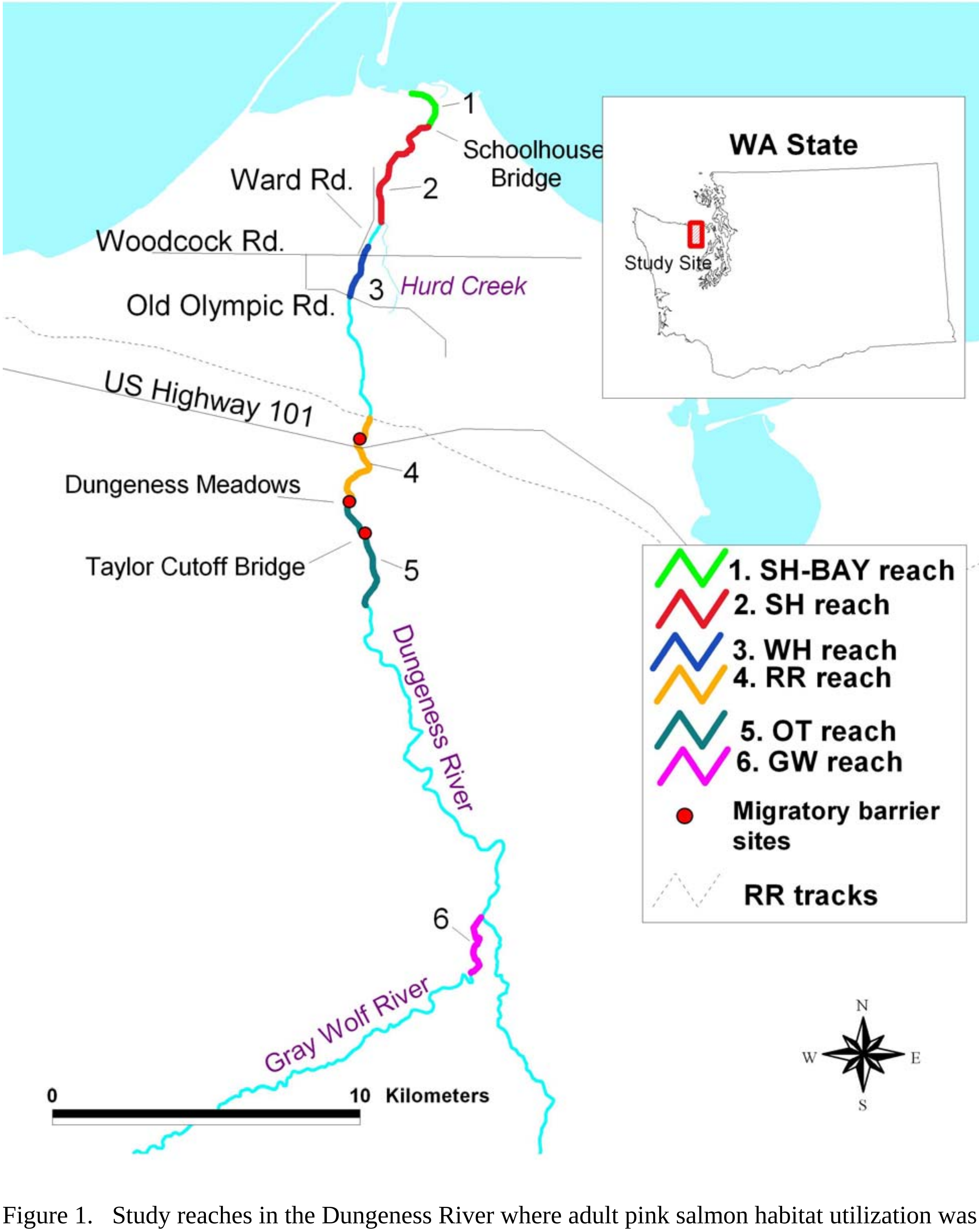

Figure 1. Study reaches in the Dungeness River where adult pink salmon habitat utilization was evaluated, and areas surveyed to evaluate potential migratory barriers.

Methods

Migratory Barriers

Potential migratory barriers to adult pink salmon migration were evaluated in the lower 17.7 km of the Dungeness River from July through September of 1995. Several potential migratory barriers to adult summer-run pink salmon were identified from the literature (Orsborn and Ralph 1994), personal communication with area biologists, and from field examination by USFWS biologists. We selected three areas to assess for physical migratory barriers from these sources. They included long riffles below the Highway 101 Bridge (610 m), along the Dungeness Meadows dike (914 m), and at the Taylor Cutoff Bridge (Figure 1). Volunteers surveyed the potential barrier sites each week from August 2 through August 31, to determine if migrating salmon were being detained. Volunteer observations were made during both the day and night, since Dungeness pink salmon may migrate at night (Pink Salmon Work Group, personal communication). Volunteers collected data on water condition (flows, visibility), weather, number of pink salmon observed, percent pink salmon actively migrating or holding, migration timing, and whether or not blockage was a problem.

Potential temperature barriers were evaluated by monitoring water temperature at three locations: Schoolhouse Bridge, Highway 101 Bridge, and near Dungeness Meadows. Water temperature was monitored by installing Stowaway temperature data loggers. This limited survey was completed to supplement information gathered by Orsborn and Ralph (1994) to further identify areas with temperatures that might block the migration of adult summer-run pink salmon.

Habitat Utilization

Within the lower 17.7 km of the Dungeness River, four study reaches were selected to ensure that all the available habitat types used by summer-run pink salmon were represented. The first reach extended from the School House Bridge to Hurd Creek (RKM 1.4- 4.3) (SH reach, Figure 1). This reach is approximately 3 km long with relatively good pool habitat, but little in-channel wood. Water depth over riffles is shallow (< 0.15 meters) during low flow discharge but passage of adult fish is facilitated by a well defined thalweg (Orsborn and Ralph 1994). The upper portion of this reach is somewhat restricted by nearshore levees that diminish meanders resulting in sections of long, straight channel. The second reach extended from Wheeler Park, just below the Woodcock Bridge to the Old Olympic Highway (RKM 5.2- 6.4) (WH reach, Figure 1). This reach was selected since it had several large woody debris accumulations, which created deep pools, and channel splits in several locations. In general, channel width is consistent, with a well defined meander pattern (Orsborn and Ralph 1994). The third reach extended from the Railroad Bridge to the lower end of the Dungeness Meadows dike (RKM 9.1- 11.9) (RR reach, Figure 1). This reach is approximately 3 km long with a highly braided streambed, long shallow riffles and sparse pool habitat with little cover. Available pool habitat occurs primarily at meander bends. Within the upper portion of this reach, the Highway 101 bridge restricts flows, creating large bedload accumulations (Orsborn and Ralph 1994). The final reach extended from the upper Dungeness Meadows dike to Otter Road (RKM 11.9- 15) (OT reach, Figure 1). The lower 1.2 km of this reach is primarily a long, straight riffle with little or no pool habitat. Bed materials in this area are coarse. Directly upstream of the powerline crossing is a deep scour pool, and from this point, the river channel resumes a more natural meander pattern for the last 0.8 km of the reach (Orsborn and Ralph 1994).

Habitat utilization by migrating adult pink salmon was assessed in the four study reaches of the Dungeness River using snorkeling methods. Snorkelers began the surveys at the downstream location of each reach. Efforts were focused on pools since these are likely the preferred holding habitat of adult summer-run pink salmon. However, riffle/run sections were also surveyed. Snorkelers entered the water at the downstream end of the habitat unit to be surveyed and moved slowly upstream. Within each pool, riffle, or run, snorkelers counted total adult pink salmon, and also juvenile and adult Chinook salmon *(O. tshawytscha*), adult bull trout (*Salvelinus confluentus*), and juvenile, first year, second year, and adult steelhead trout (*O. mykiss*). Steelhead trout were not surveyed until the third week of the survey.

Upon identifying an adult summer-run pink salmon, the snorkeler determined if the fish was holding, migrating, or fleeing. If it was determined the fish was holding, the location was marked using a lead weight with a ribbon attached. Several physical measurements were then taken at the location where the fish was holding including: water depth at the holding location; fish focal depth; mean water column velocity; fish focal velocity; and distance to nearest cover. Additional information on the type, function, and surface area of the cover present was collected according to the categories set forth by IFIM procedures (Bovee 1986) (Table 1). The surveyors also noted if the fish was located in full shade, partial shade or sunlight, and the percent dominant and subdominant substrate type below the fish (Table 2). The procedure for measuring mean column velocity was as follows: in waters less than 75 centimeters (cm), a single measurement at 60 percent of the total depth was taken; in waters greater than 75 cm, measurements were taken at 20 and 80 percent of the total depth and averaged; and in turbulent waters, measurements were taken at 20, 60, and 80 percent of the total depth. In these cases, the velocities at 20 and 80 percent depth, plus two times 60 percent depth were summed, then divided by four to obtain a reliable estimate of the mean (Bovee 1986).

Following physical measurements, snorkelers moved upstream until they had passed two pool/riffle complexes before re-entering the water to continue their survey. This was done to prevent duplicate observations on the same fish during that day. Surveys were completed on two to three successive days of each week. The first day's survey was completed on the upper reach, with successive surveys completed in downstream sections. This eliminated observations on the same group of fish as they migrated upstream.

Table 1. Cover type and function categories used to evaluate the importance of cover to adult pink salmon in the Dungeness River (from Bovee 1986).

Code	Cover type	Cover function	Examples
NONE	No cover	No cover	Open water, deep pools
IOB	Instream object	Velocity shelter	Large rocks, ledges, partially buried logs
IOV	Instream overhead	Direct visual isolation	Undercut bank, floating vegetation, log jams, turbulence
OO	Offstream overhead	Indirect visual isolation	Overhanging canopy, shadows
IO	Combination of IOB and IOV	Velocity shelter and visual isolation	Root wads, brush, vegetation, log jams

Table 2. Substrate classification and size categories used to evaluate the importance of substrate to adult pink salmon in the Dungeness River (from Bovee 1986).

Substrate	Size range (mm)
Organic Detritus (log, leaves)	n/a
Vascular Plants	n/a
Attached Algae	n/a
Clay/Silt	0.0024 - 0.062
Sand	0.062 - 2.0
Fine Gravel	2.0 - 16
Coarse Gravel	16 - 64
Small Cobble	64 - 128
Large Cobble	128 - 256
Small Boulders	256 - 512
Medium Boulders	512 - 1024
Large Boulders	1024 - 2048
Bedrock	n/a

A section of the Gray Wolf River was surveyed for summer-run pink salmon holding habitat on one occasion during the survey period due to turbid water conditions in the lower survey reaches (GW reach, Figure 1). The Gray Wolf River was also snorkeled at the end of the survey period to determine the upstream distribution for the summer-run pink salmon migration. No habitat utilization data were collected on the later survey.

Additional surveys were conducted from the Schoolhouse Bridge to Dungeness Bay (SH-BAY reach, Figure 1), and from Schoolhouse Bridge to Hurd Creek primarily to count fall pink salmon. These reaches were surveyed to determine the availability of fall pink salmon to support hatchery-based restoration efforts for the Dungeness River. No habitat utilization data were collected on these surveys.

Within each reach, pools, riffles, and runs were surveyed and fish presence or absence was documented accordingly. Glides and shallows were categorized as riffles for the analysis. When a group of fish was observed at a location, data were recorded based on the range of conditions used by the entire group (e.g., depth 1.1-1.3 m). However, the mean value (e.g., 1.2 m) was used for data analysis. Habitat parameters (range, mean, median, and 95% CI) were summarized according to holding groups, not by individual fish, as this would skew the statistics since measurements were not taken for each individual fish. We performed linear regressions and analysis of variance (ANOVA) for each habitat variable and cover type to identify associations between fish abundance and habitat used. Cover utilization by holding summer-run pink salmon was also determined by the percentage of groups of adult pink salmon using each of the cover types, and by chi-square analysis of cover versus no cover.

Linear regressions and ANOVA were performed using *SYSTAT®10* software. Statistical significance was assessed at the 0.05 level. The original count data were not normal ($P < 0.0001$), however the log transformation failed to normalize the data ($P = 0.0089$). Since log transformation data were less normalized, the count data were used for regression analysis. Regression plots were visually inspected for normality, and major outliers were removed from the final analysis of cover.

Results

Migratory Barriers

No pink salmon were observed migrating through or detained at any of the three potential barrier sites. All three riffles were surveyed twelve days throughout the month of August. The Highway 101 Bridge site was surveyed 12 times, the Dungeness Meadows site 6 times, and the Taylor Cutoff Bridge site 6 times. Water conditions were clear but higher than previous years due to abnormally high snow-pack in 1995 (Figure 2). Streamflow was taken from the USGS gage station 1204800, which is approximately one kilometer upstream of the irrigation withdrawals. Streamflows averaged 7,248 cm/s during August, ranging from a high of 12,649 cm^3/s early in the month to a low of 5,181 cm/s at the end of the month. These flows were on average 2,816 cm/s higher in 1995 than flows during August in 1994.

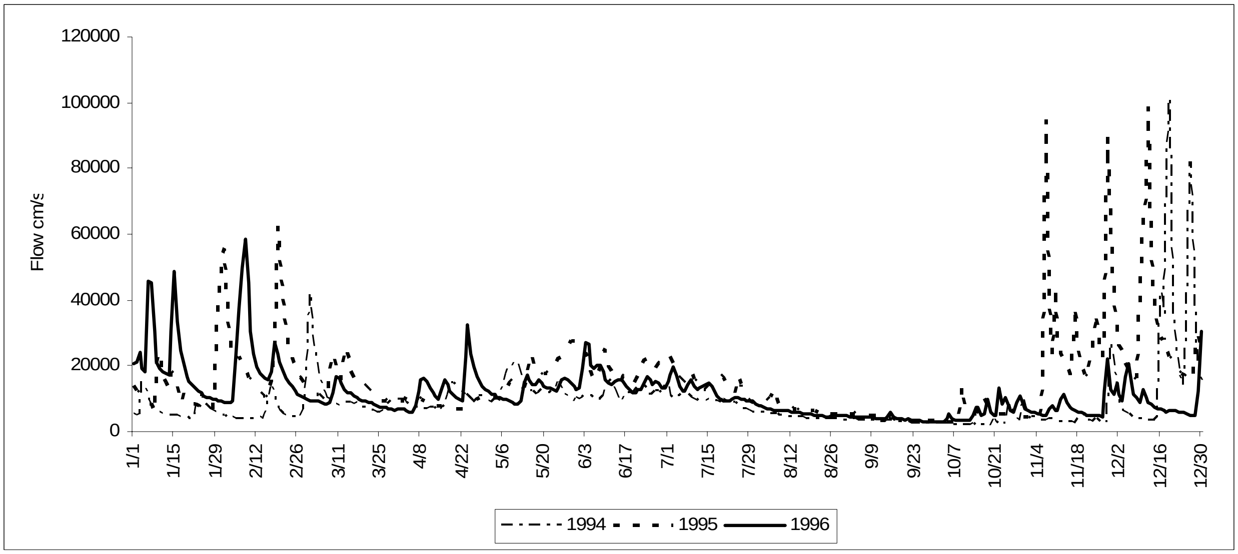

Figure 2. Dungeness River discharge upstream of irrigation withdrawals during 1994-1996.

No apparent temperature barriers were indicated based on temperature data collected by the Stowaway data loggers located at the Schoolhouse Bridge, Highway 101 Bridge, and near the Dungeness Meadows. Temperatures progressively increased in a downstream direction, with the highest average temperatures recorded at the Schoolhouse Bridge (Figure 3). The Dungeness Meadows site ranged from a minimum temperature of 7.4, to a maximum of 15.4º C; while the Highway 101 Bridge had a minimum of 7.8, and a maximum of 16.1º C; and the Schoolhouse Bridge had a minimum of 8.8, and a maximum of 17.2º C (Figure 4). Mean daily temperature for all three locations ranged from 10.6 to 12.1º C.

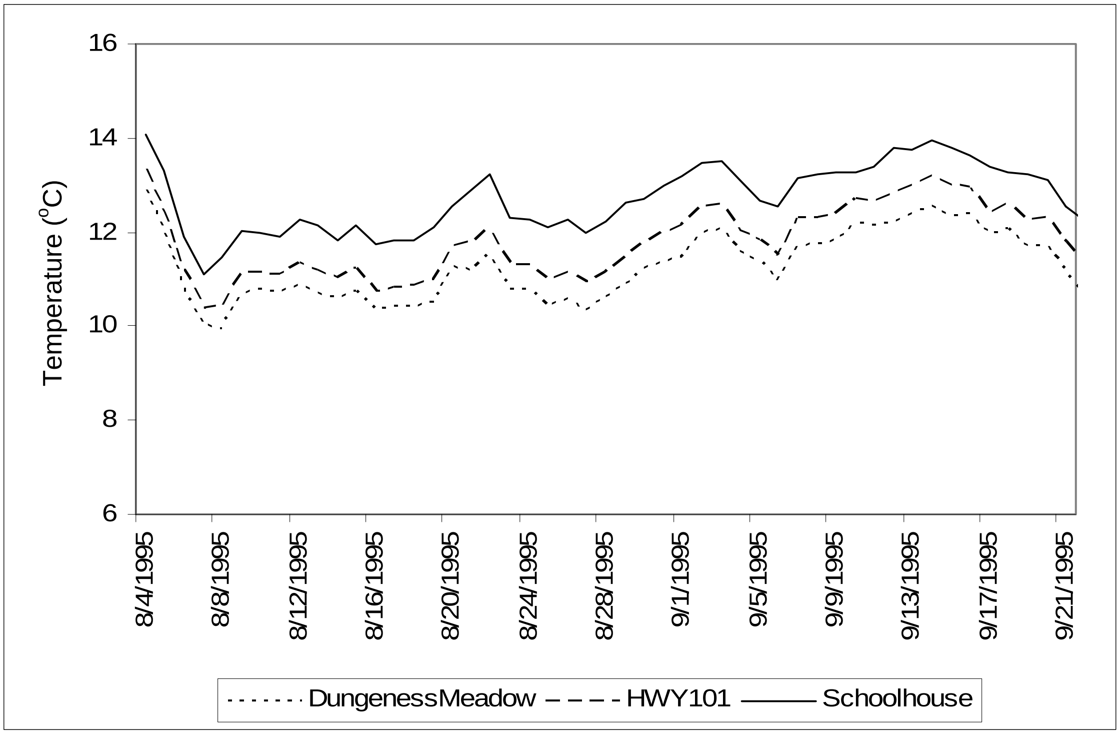

Figure 3. Average daily temperatures in selected reaches of the Dungeness River during our study.

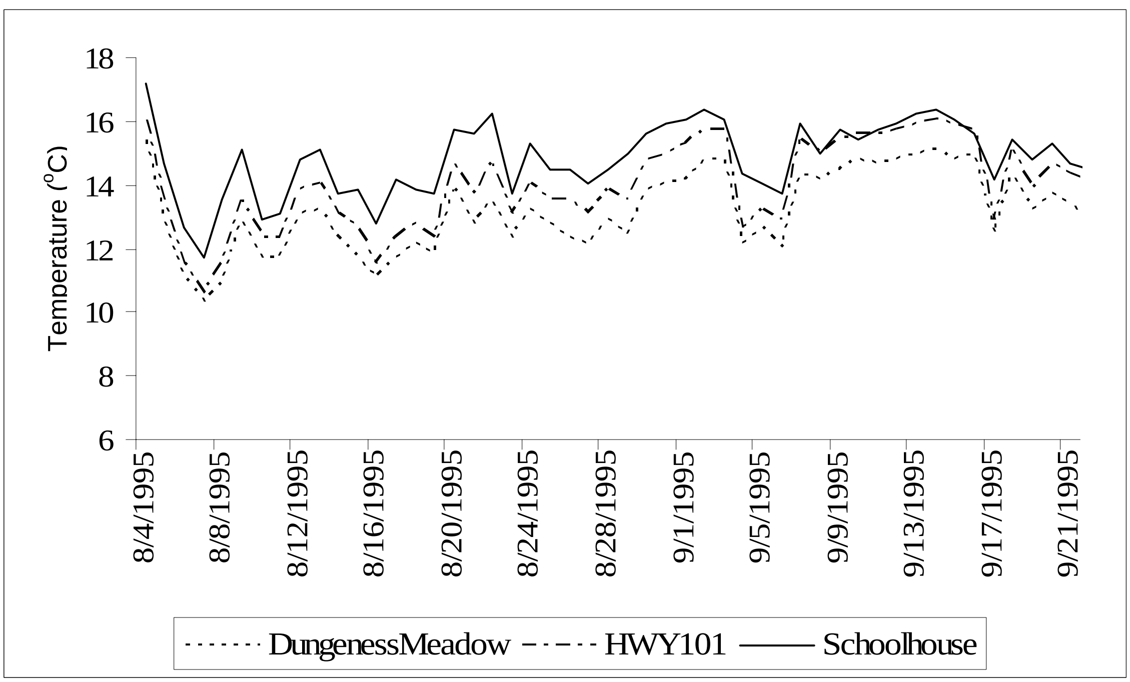

Figure 4. Maximum daily temperatures in selected reaches of the Dungeness River during our study.

Habitat Utilization

Pools encompassed 80% of sampled habitat, and in general, fish (any species) were found in at least 90% of each of the habitat types sampled (Table 3). Most of the habitats sampled (76%) were in the RR and SH reaches where the majority of sampling occurred (Table 4).

Table 3. Total number of different habitat types sampled during this study.

Habitat type	Total Sampled	% of habitats sampled	Habitats with fish (all species)
Pool	203	80	191
Riffle	17	6	16
Run	35	14	32
Total	255		239

Table 4. Total number of habitat types sampled in each study reach during this study.

Habitat	SH-BAY	SH	WH	RR	OT	GW	Total
Pool	3	69	20	88	12	11	203
Riffle	1	8	0	6	0	2	17
Run	0	20	1	2	12	0	35
Total	4	97	21	96	24	13	255

The number of fish of each species and age-class is listed in Table 5. Overall water clarity was fairly good, with the lowest visibility occurring during the first two weeks of the survey. No fish were observed during the first survey of the RR reach on July 18, because water clarity was poor. Adult pink salmon were first observed during the July 24 survey. Numbers observed in the SH and RR reaches increased to a peak in mid-August. The highest count was observed in the SH reach on September 7. However, all habitats were surveyed during this survey (to look for fall pink salmon-see discussion), while only a portion of the habitats were surveyed during previous surveys in order to minimize duplicate observations of holding fish.

Table 5. Total number of fish of different species and size classes observed in each reach during each survey.

Date	Reach	Pinks	Ad.CH[1]	Juv.CH[1]	Bulltrout[1]	Ad.ST[1]	ST.2+[1]	ST.1+[1]	ST.0+[1]
7/18/95	RR	0	0	0	0	0	0	0	0
7/24/95	RR	12	2	7	3	0	0	0	0
7/25/95	SH	23	0	0	0	0	0	0	0
7/31/95	RR	83	4	19	2	3	0	0	0
8/3/95	SH	92	5	7	0	2	0	0	0
8/7/95	GW	50	0	0	4	0	0	0	0
8/9/95	SH	76	2	1	1	2	16	188	55
8/14/95	RR	162	5	3	6	3	6	268	145
8/15/95	SH	301	8	0	0	2	3	93	42
8/21/95	RR	150	4	2	3	4	22	214	266
8/22/95	SH	263	5	2	2	2	1	105	35
8/28/95	OT	66	6	9	9	4	5	273	188
8/29/95	SH-BAY*	26	0	0	0	0	0	0	0
	WH	180	15	2	8	2	0	158	132
9/7/95	GW*	162	0	0	0	0	0	0	0
	SH*	310	0	0	0	0	0	49	119
Totals		1956	56	52	38	24	53	1348	982

* primarily counted pink salmon, no other measurements noted
[1]Adult Chinook (Ad.CH), Juvenile Chinook (Juv.CH), Adult Steelhead (Ad.ST), Steelhead 2yr+ (ST.2+), Steelhead 1yr+ (ST.1+), and Juvenile Steelhead (ST.0+), Bull Trout ranged from 200 – 450 mm.

In general, summer-run pink salmon were found holding in pool habitat 80% of the time, runs 14%, and riffles 6%. Distribution of holding pink salmon in the habitat types was as expected when accounting for total habitats surveyed, with no selection for habitat type. These distributions are broken down by reach in Table 6. The SH reach had the greatest number of adult pink salmon utilizing riffle and run habitat.

Table 6. Distribution of groups of summer-run pink salmon holding in different habitat types for each survey reach.

Habitat	SH	WH	RR	OT	GW	Total
Pool	37	7	28	4	6	82
Riffle	5	0	1	0	1	7
Run	13	0	0	1	0	14
Total	55	7	29	5	7	103

Adult pink salmon prefer to hold in shaded areas. Seventy-seven groups were observed holding in shade or partial shade (Table 7). Only 14% were observed holding in sunlight. No shade/sunlight observations were recorded for 13 of the 103 total groups surveyed. Significantly more groups of pink salmon were observed holding in full shade than would be expected assuming shaded and unshaded areas were available in equal amounts (chi-square: $P < 0.0001$).

Table 7. Number of groups of summer-run pink salmon observed holding in shade, no shade, and partial shade.

Shade	Total Groups	%	chi-square
No	13	14	27.38
Yes	72	80	9.68
Partial	5	6	0
Grand total	90		37.06

Sample sizes were too small to analyze the influence of the individual substrate categories listed in Table 2. Therefore, we combined our observations into four major categories: boulders; cobble; gravel; and sand/silt. The dominant substrates used by groups of holding pink salmon were cobble and gravel, with 51% of summer-run pink salmon observed holding over cobble, and 39% over gravel (Table 8). Total individual fish within each group was similarly distributed over cobble and gravel (Figure 5). We did not evaluate substrate preference by adult pink salmon, because substrate availability was not measured.

Table 8. Number and percent of groups of summer pink salmon holding above different dominant substrates.

Dominant Substrate	Total Groups	%
Boulder	8	8
Cobble	52	51
Gravel	39	39
Sand/Silt	2	2
Grand Total	101	

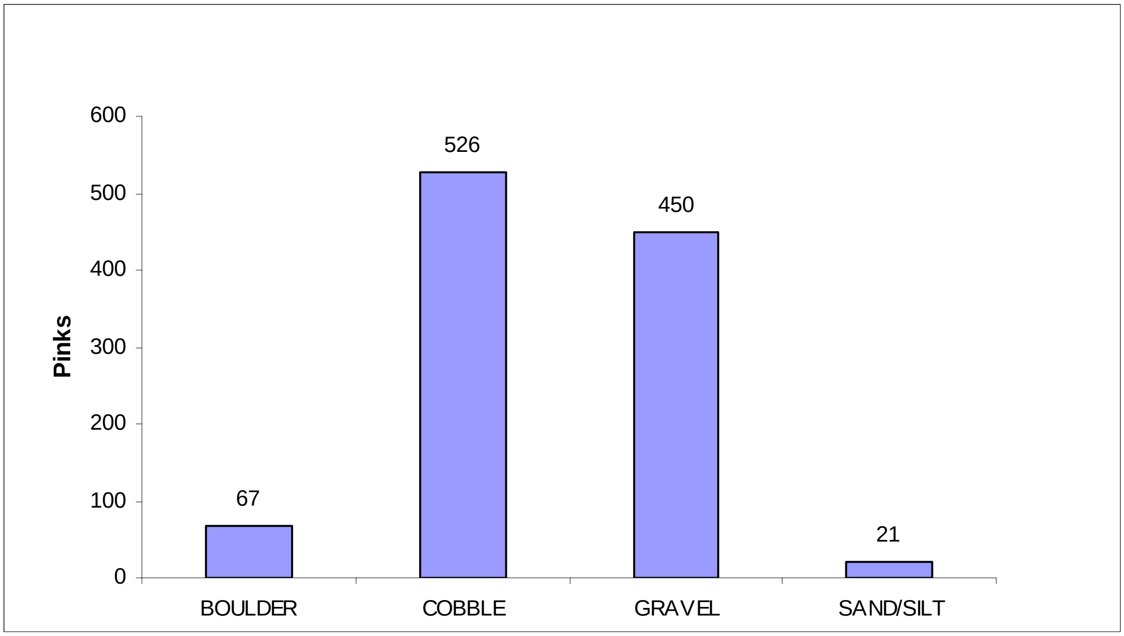

Figure 5. Total numbers of summer-run pink salmon holding over different dominant substrate classes.

The dominant substrate used by holding summer pink salmon varied for the different study reaches (Table 9). Cobble and gravel were the only dominant substrate types used in the SH and WH reaches. Boulders, cobble, gravel, and sand were dominant in the RR reach; however, cobble was the most common. Boulders, cobble, and gravel were dominant in the OT and GW reaches. Over half of all dominant substrate samples were from the SH reach (n = 52), weighting the total percentage of dominant substrates more heavily towards gravel. If the SH reach is removed from analysis, total dominant substrate percentages are 61% cobble, 17% gravel, 17% boulder, and 5% sand. Subdominant substrate utilization was more evenly spread among the four major substrate categories (Table 10). Cobble and gravel were the most common subdominant substrates used, with 31% and 28% of the total observations, respectively. Boulders were the least common subdominant substrate used by adult pink salmon.

Table 9. Percentages of different dominant substrates utilized by holding summer-run pink salmon for each survey reach.

Reach	Substrate	Groups of pink salmon[1]	Average % substrate[2]
SH	Gravel	30	74
	Cobble	22	69
WH	Gravel	2	55
	Cobble	5	77
RR	Sand	2	80
	Gravel	2	60
	Cobble	19	66
	Boulder	4	66
OT	Gravel	1	50
	Cobble	3	70
	Boulder	1	100
GW	Gravel	3	75
	Cobble	1	60
	Boulder	3	57

[1] Total groups of holding pink salmon observed throughout the survey period for each survey reach.
[2] Average of each substrates percentages throughout the survey period for each survey reach.

Table 10. Number and percent of groups of summer-run pink salmon holding above different subdominant substrates.

Subdominant Substrate	Total Groups	%
Boulder	14	16
Cobble	28	31
Gravel	25	28
Sand/Silt	22	25
Grand Total	89	

Cover surface area of IO, IOV, IOB, and OO (see Table 1) explained little of the variation in the total numbers of holding pink salmon for each of the different cover types based on linear regression, and the relationship between cover type and pink salmon utilization was poor (IO: $n = 12$, $P = 0.9178$, $r^2 = 0.00$; IOV: $n = 25$, $P = 0.6748$, $r^2 = 0.01$; IOB: $n = 25$, $P = 0.0832$, $r^2 = 0.12$; and OO: $n = 10$, $P = 0.1792$, $r^2 = 0.28$). However, total numbers of summer-run pink salmon were most positively influenced by the surface area of IOB cover (see Figure 6, for IOB regression plot). Cover surface area utilized by adult pink salmon averaged 17 m^2, with the majority of observations under 10 m^2.

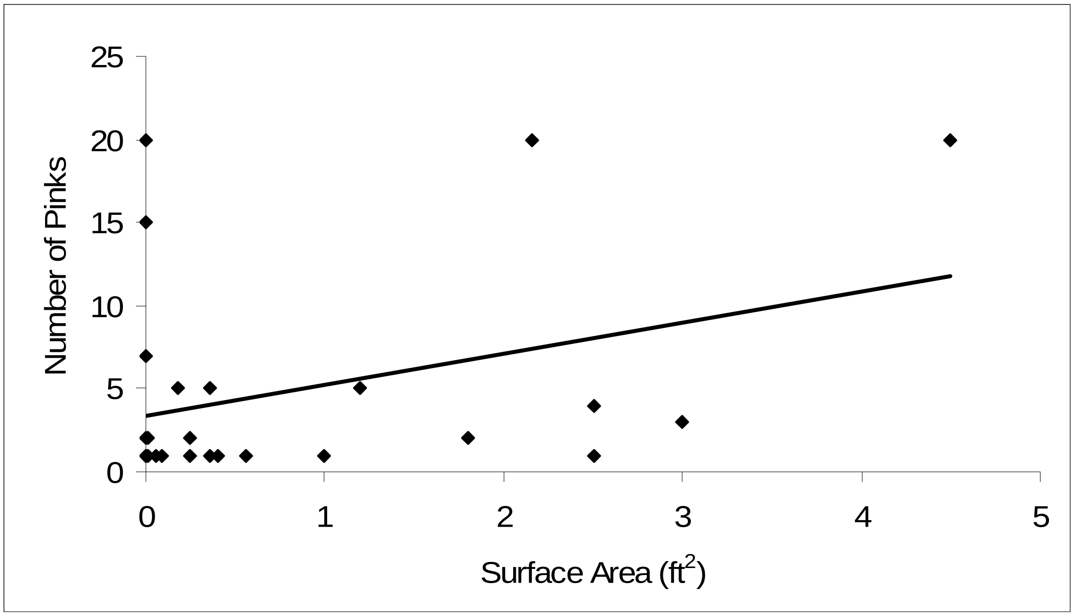

Figure 6. IOB surface area utilization by groups of holding summer-run pink salmon in the Dungeness River (1 outlier removed).

Adult pink salmon used cover significantly more than areas lacking cover (*Chi-square*: $P < 0.0001$), assuming cover and non-cover areas were equally represented in the river (Table 11). Only 15% of adult pink salmon were observed in areas lacking cover. IOV and IOB were the most common cover types used. IOB cover was primarily provided by boulders, IOV was primarily logs, trees, and depth, IO was primarily trees, logs, and branches, and OO cover was primarily trees (Table 12).

Table 11. Number of pink salmon groups observed holding near each cover type.

Cover type	Total groups	%
IO	13	13
IOB	26	26
IOV	36	36
OO	10	10
NONE	15	15
Grand Total	100	

Table 12. Percentages of different cover objects by cover type utilized by holding summer-run pink salmon in the Dungeness River.

Cover type	Cover object	Total groups (n)	%
IO	Boulder/Turbulence/Wood	2	16
	Branch	3	25
	Log	2	17
	Rootwad/Log	1	8
	Tree	4	34
IOB	Boulder	11	47
	Large Organic Debris	2	8
	Log	5	21
	Large Woody Debris	2	8
	Rootwad	1	4
	Tree	2	8
	Velocity	1	4
IOV	Branch	2	8
	Depth/Bubble Curtain/Undercut Bank	3	12
	Large Organic Debris	2	8
	Log	6	24
	Large Woody Debris	3	12
	Rootwad/Log	1	4
	Tree	7	28
	Turbulence	1	4
OO	Riparian Vegetation	2	25
	Tree	6	75

Adult summer-run pink salmon generally held in water depths greater than 1 m, but values ranged from 0.6 m to 2.7 m (Table 13). Adult pink salmon generally selected focal positions close to the bottom, with 75% of holding pink salmon observed within 0.21 m or less. Relative depth ranged from 0.38 to 0.97 m, and the median value was 0.90 m, or 90% of the mean depth. Mean water and focal velocities used by adult pink salmon ranged from 2.9 centimeters per second (cm/s) to 121.3 cm/s, and 0.3 cm/s to 113.1 cm/s, with mean values of 57.8cm/s and 37.07 cm/s respectively. Adult pink salmon were generally within 1.25 m of cover, but were also found up to 50 m from cover. Statistical summarization of habitat variables for each sampling reach can be found in Appendix A (Tables A1, A2, A3, A4).

Table 13. Summary statistics for each of the habitat variables used by adult summer-run pink salmon in the Dungeness River.

Habitat variable	N	Mean	95% CI
Focal depth (m)	101	1.18	0.08
Water depth (m)	101	1.34	0.08
Mean water velocity (cm/s)	88	57.81	5.60
Focal velocity (cm/s)	95	37.07	3.93
Relative depth (m)	101	0.88	0.02
Distance to cover (m)	92	1.21	1.16

Few of the habitat variables were statistically related to pink salmon utilization. Pink salmon abundance was positively related to water depth (n = 95, $P < 0.0001$, $r^2 = 0.22$), and focal depth (n = 95, $P < 0.0001$, $r^2 = 0.21$), but the relationships were poor. Mean water velocity (n = 84, $P > 0.05$, $r^2 = 0.030$), and focal velocity (n = 89, $P > 0.05$, $r^2 = 0.04$) were not significantly related to pink salmon utilization. Despite poor relationships, trend lines indicated that: as water and focal depth increased, the number of pink salmon in each group increased; and as mean water and focal velocity increased, the number of pink salmon in each group decreased.

Discussion

Migratory Barriers

We did not identify any migratory barriers through direct visual observations at the three selected sites within the Dungeness River. Streamflows in August were 1500 to 7300 cm^3/s higher in 1995 than in 1994, with an average of 7248 cm^3/s in 1995 compared to an average of 4432 cm^3/s in 1994. These higher streamflows may have permitted full adult passage in 1995, which in previous years could have blocked adult passage at these potential barrier sites. The limiting factors analysis in 1999 identified additional low flow migration barriers from the mouth of the Dungeness River up to the Schoolhouse Bridge, where slip face cascades may block fish passage at low tides, and from Hurd Creek up to Ward Bridge, where additional slip face cascades may present a migration barrier (Haring 1999). Hiss (1995) used multiple regressions to assess the importance of nine environmental factors in return to escapement for Dungeness pink salmon from 1959-1993, and found low flows during adult pink salmon migrations ranked fourth in importance.

Total Dungeness pink salmon escapement for 1995 was 8,352. In general, Dungeness pink salmon escapements have been under 10,000 since 1980, with an abnormal high return of 80,344 in 2001 due to favorable weather and ocean conditions, and high streamflows during adult migrations. Escapement for Dungeness pink salmon was estimated to be at 15,116 for 2003, because of this fairly high brood return in 2001 (Bill Freymond, Washington Department of Fish and Wildlife, personal communication). In 1998, a Trust Water Rights Agreement was developed between the Dungeness Agricultural Water Users Association and the Department of Ecology, which expanded and formalized the earlier version of the voluntary water withdrawal restriction of no more than 50% of instream flows (Clark and Clark 1995; Haring 1999; Seiter et al. 2000). However, these reductions in irrigation withdrawals may have little effect on river flows if the river continues to aggrade in the lower reaches as it has historically (Bonar et al. 1989).

No apparent temperature barriers to migration of adult pink salmon were identified by this study. Optimal temperatures for upstream pink salmon migration fall between 7.2 and 15.6º C (Bjornn and Reiser 1991). Maximum temperatures exceeded 15.6º C periodically at the Highway 101 and Schoolhouse Bridge sites from August through September of 1995, but did not exceed 20º C, which has been cited as the threshold for delays of migrating salmon (Bjornn and Reiser 1991; Quinn et al. 1997). The Dungeness River is rated A (excellent) for temperature standards by the Department of Ecology, with maximum summer temperatures less than 18º C (Orsborn and Ralph 1994). Puntledge River adult pink salmon exposed to three temperature regimes (averaging 15.1º C , 18.4º C , and 21.3º C) prior to spawning experienced significant ($P < 0.05$) increases of adult mortality, delayed maturation rates, and reduced gamete viability in high water temperatures (Jensen et al. 2004). Most importantly, there were significant ($P < 0.05$) differences between the ambient and chilled groups, indicating that even in years with moderate temperatures, pink salmon will experience increased mortality, and spawning delays. Bonar et al. (1989) states that temperatures of 17º C and low dissolved oxygen levels associated with drought conditions have killed many adult pink salmon migrating in Alaskan streams. Higher than average flows may have influenced temperatures in the Dungeness River during our survey. Significant changes to migratory behavior of sockeye salmon in the Columbia River are due to the correlating effect of decreased stream flows and increased stream temperatures (Quinn et al. 1997). Ebersole et al. (2003) found that as channel width-depth ratios increased, the frequency of cold water patches declined, along with declines in rainbow trout and Chinook salmon abundance. This suggests that the elevated stream flows observed during our survey may have decreased the temperatures normally found in the river, providing greater access to cooler refugia and lower probability of thermal migratory blockages.

Volunteer observations of the diel migration of adult pink salmon were inconclusive, as no fish were seen during the day or night. However, while sampling, we observed adult pink salmon migrating during the day during the habitat utilization surveys. Seton River pink salmon have been found to migrate during the day in the Fraser River, based on data collected using electromyogram telemetry (Hinch et al. 2002).

We conducted two snorkel surveys, in the SH-BAY and SH reaches with the purpose of counting adult pink salmon. These surveys were completed to assess the abundance and distribution of fall pink salmon, to assist with planning and implementation of a restoration plan for this stock using hatchery augmentation (DOI 1994). A weir was placed in the SH-BAY reach to capture adult fall pink salmon as they entered the river. Captured fish were to be genetically identified as fall or summer-run, with summer-run pink salmon returned to the river, and fall run retained and spawned in the hatchery. Our first survey was to assess how many pink salmon were below the weir, to determine how many pink salmon the weir crew could anticipate handling. We observed only 26 pink salmon during this survey and most were already above the weir. The second survey in the SH reach was to assess how many fish were immediately upstream of the weir, to determine if the fall pink salmon had entered the river prior to weir installation. The observation of 350 adult pink salmon confirmed that adult pink salmon had entered the river prior to weir installation. Dungeness River fall pink salmon apparently enter the river, hold for some period of time (unknown), and then 'fall back' to spawn. We assume they 'fall back' since most were observed well upstream of the weir, but numerous redds were constructed just upstream of the weir. This is a unique life history trait for fall pink salmon, which are generally assumed to enter the river just before spawning. Therefore, the holding data collected for summer pink salmon will be useful for protecting or restoring holding habitat for fall pink salmon as well.

Habitat Utilization

We describe habitat utilization by adult summer-run pink salmon in this report. This should not be confused with habitat preference, since habitat availability must be assessed to determine preference (Bovee 1986), and we did not assess habitat availability. Assessing habitat availability would have required that all habitat within the study reaches be measured for depth, mean water column velocity, substrate, cover, etc., during each survey. This was beyond the scope of this study.

Adult summer-run pink salmon preferred to hold in shaded areas with cover. Wampler (1986) also found that 86% of holding adult Chinook (N=383) were located in full or partial shade in the Dungeness River. Shade utilization is directly related to cover type and function utilization, as shade is supplied by the various cover elements. The majority of adult pink salmon were holding under IOV cover provided by trees, logs, and large woody debris. Wampler (1986) found that overhead wood was the preferred cover utilized by holding adult Chinook in the Dungeness River. The lower 17.4 km of the Dungeness River were identified as having poor large woody debris conditions, and little riparian cover, with the exception of the section from the Old Olympic Bridge to the Highway 101 Bridge (Haring 1999). Our analysis is based on the assumption that shade and non-shade areas, and cover and non-cover areas were equally available. The conclusions of Haring (1999) suggest that this was a conservative assumption, and that non-shade and non-cover areas were available in greater quantities. This suggests that our findings of shade and cover are likely underestimated. Thus, shade and cover appear to be extremely important habitat features for holding adult summer pink salmon in the Dungeness River. Most adult pink salmon we observed near cover were within 1 m distance, with the highest distances to cover in the RR reach.

There was a general progression in dominant substrate size utilized by holding pink salmon, from smaller substrates in the lower SH and WH reaches, to larger substrates in the higher OT and GW reaches. This would be expected, as the Dungeness River system is characterized by larger boulder and cobble substrates in the upper reaches, and smaller sand and gravel substrates lower in the floodplain (Orsborn and Ralph 1994). Orsborn and Ralph (1994) found small patches of suitable spawning gravels for pink salmon and Chinook salmon near the Schoolhouse Bridge, and from Hurd Creek to Ward Bridge. We observed adult summer-run pink salmon utilizing cobble and gravel as dominant substrates. Wampler (1986) found spring Chinook prefer holding over small cobble and large gravel in the Dungeness River. There did not appear to be any specific pattern for subdominant substrate utilization by adult pink salmon, as each of the four categories was utilized similarly. The only distinct exception was that on a reach specific basis, the RR reach had the greatest frequency of subdominant boulder observations (n = 11), compared to only one observation in the SH and GW reaches each. The RR and GW reaches also had the greatest frequency of dominant substrate boulder observations (n = 4 and 3, respectively). Haring (1999) identified pool habitat at the RR reach as limited to meander bends with little cover and high velocities. The majority of our observations of holding pink salmon were within pool habitat, thus, higher velocities are likely moving the smaller substrates downstream.

Pink salmon are characterized as being weaker swimmers that have greater difficulty overcoming velocity and physical barriers when compared to other salmon (Heard 1991). Recent research indicates that river reaches that have constrictions, and high velocities associated with complex hydraulics, cause pink salmon to use relatively high levels of energy during migration (Hinch et al. 2002; Standen et al. 2002). Based on this information, summer-run pink salmon face a greater number of obstacles as they migrate longer distances to spawning grounds than fall-run pink salmon stocks. Maximum allowable velocity for adult pink salmon migration is 200 cm/s (Raleigh and Nelson 1985). Holding summer-run pink salmon were never observed utilizing mean column velocities greater than 120 cm/s in the Dungeness River, and focal velocities utilized were primarily less than 60 cm/s. Wampler (1986) found that spring Chinook did not select lower velocities relative to the availability of higher velocities in the Dungeness River, but consistently preferred facing into focal velocities less than 61 cm/s and at depths less than 0.21 m from the stream bottom. Adult pink salmon prefer holding at focal depths close to the stream bottom, generally within 0.21 m in the Dungeness River. In the Fraser River system, pink salmon have been observed migrating in tight groups close to shore near the stream bottom, where turbulence and velocities are generally lower (Standen et al. 2002).

Minimum allowable water depth to allow for pink salmon migration is from 0.09 m to 0.18 m (Raleigh and Nelson 1985). The majority of adult pink salmon in the Dungeness River preferred holding at depths between 1 m and 2 m, with a minimum depth of 0.5 m. Even though Wampler (1986) found spring Chinook depth utilization to be primarily at 1 m, there was a shift in preference to 4 m due to the lesser availability of deep pools in the Dungeness River. Wampler (1986) compared the number of fish per stream surface area in segments where deep (4 m) pools existed, and found that deeper stream segments attract and provide holding habitat for the greatest number of spring Chinook relative to the availability of deep pools. Orsborn and Ralph (1994) found that the average number of pools (> 1 m deep) per mile in the Dungeness River below river mile 10.8 was from 15 to 20, with the fewest in the Dungeness Meadows reach (3.9 pools/mile). This suggests that pool habitat appears to be an extremely important habitat feature for holding adult summer pink salmon in the Dungeness River. Greater depths provide increased protection from predators, as fish have a less visible profile near the stream bottom, and less energy is expended in lower velocities at deeper depths (Wampler 1986). As previously stated, adult pink salmon were positioned near the stream bottom, with an average relative depth of 0.16 m. Relative depth was fairly consistent throughout the reaches, indicating that fish were utilizing focal depths close to the stream bottom despite differing water depths and stream morphology.

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Appendix A:

Table A1. Summary statistics for water and focal depth utilized by holding summer-run pinks for each survey reach.

		Water depth (m)			Focal depth (m)		
Date	Reach	N	Mean	95% CI	N	Mean	95% CI
07/24/1995	RR	2	0.70	0.20	2	0.43	0.25
07/25/1995	SH	3	1.25	0.36	3	1.02	0.16
07/31/1995	RR	7	1.20	0.35	7	0.99	0.27
08/03/1995	SH	10	1.49	0.18	10	1.32	0.18
08/07/1995	GW	7	1.12	0.26	7	0.93	0.25
08/09/1995	SH	11	1.38	0.22	11	1.24	0.20
08/14/1995	RR	6	1.29	0.28	6	1.19	0.30
08/15/1995	SH	16	1.44	0.12	16	1.34	0.12
08/21/1995	RR	13	1.16	0.14	13	1.01	0.15
08/22/1995	SH	14	1.43	0.16	14	1.26	0.16
08/28/1995	OT	5	1.08	0.56	5	0.90	0.38
08/29/1995	WH	7	1.81	0.51	7	1.62	0.47

Table A2. Summary statistics for mean water and focal velocity utilized by holding summer-run pinks for each survey reach.

		Water velocity (cm/s)			Focal velocity (cm/s)		
Date	Reach	N	Mean	95% CI	N	Mean	95% CI
07/24/1995	RR	0	0	0	2	56.69	112.78
07/25/1995	SH	0	0	0	3	56.49	32.23
07/31/1995	RR	7	56.43	22.75	7	41.28	11.89
08/03/1995	SH	7	79.97	19.98	8	44.92	13.13
08/07/1995	GW	7	47.31	13.57	7	29.83	5.85
08/09/1995	SH	10	49.95	15.86	10	42.58	13.07
08/14/1995	RR	6	42.32	28.46	6	26.87	7.75
08/15/1995	SH	16	68.20	13.41	16	31.91	7.92
08/21/1995	RR	13	61.90	12.54	13	38.83	11.18
08/22/1995	SH	13	57.08	13.99	13	38.73	9.74
08/28/1995	OT	3	63.99	28.63	4	30.86	13.41
08/29/1995	WH	6	36.25	8.67	6	25.45	7.46

Table A3. Summary statistics for distance to cover utilized by holding summer-run pinks for each survey reach.

		Distance to cover (m)		
Date	Reach	N	Mean	95% CI
7/24/1995	RR	3	1.13	0.26
7/25/1995	SH	3	0.17	0.33
7/31/1995	RR	7	0.05	0.09
8/3/1995	SH	10	0.73	0.56
8/7/1995	GW	6	0.25	0.34
8/9/1995	SH	10	0.31	0.27
8/14/1995	RR	6	3.83	6.54
8/15/1995	SH	12	0.48	0.34
8/21/1995	RR	13	3.99	7.67
8/22/1995	SH	12	0.4	0.37
8/28/1995	OT	4	1.53	0.9
8/29/1995	WH	7	0.43	0.4

Table A4. Summary statistics for relative depth utilized by holding summer-run pinks for each sampling reach.

		Relative depth (m)			
Date	Reach	N	Range	Median	95% CI
7/24/1995	RR	2	0.54	0.65	0.54
7/25/1995	SH	3	0.27	0.85	0.15
7/31/1995	RR	7	0.23	0.84	0.05
8/3/1995	SH	10	0.17	0.88	0.04
8/7/1995	GW	7	0.28	0.82	0.07
8/9/1995	SH	11	0.12	0.9	0.02
8/14/1995	RR	6	0.17	0.93	0.05
8/15/1995	SH	16	0.11	0.93	0.02
8/21/1995	RR	13	0.28	0.92	0.05
8/22/1995	SH	14	0.12	0.88	0.02
8/28/1995	OT	5	0.26	0.92	0.1
8/29/1995	WH	7	0.06	0.9	0.02